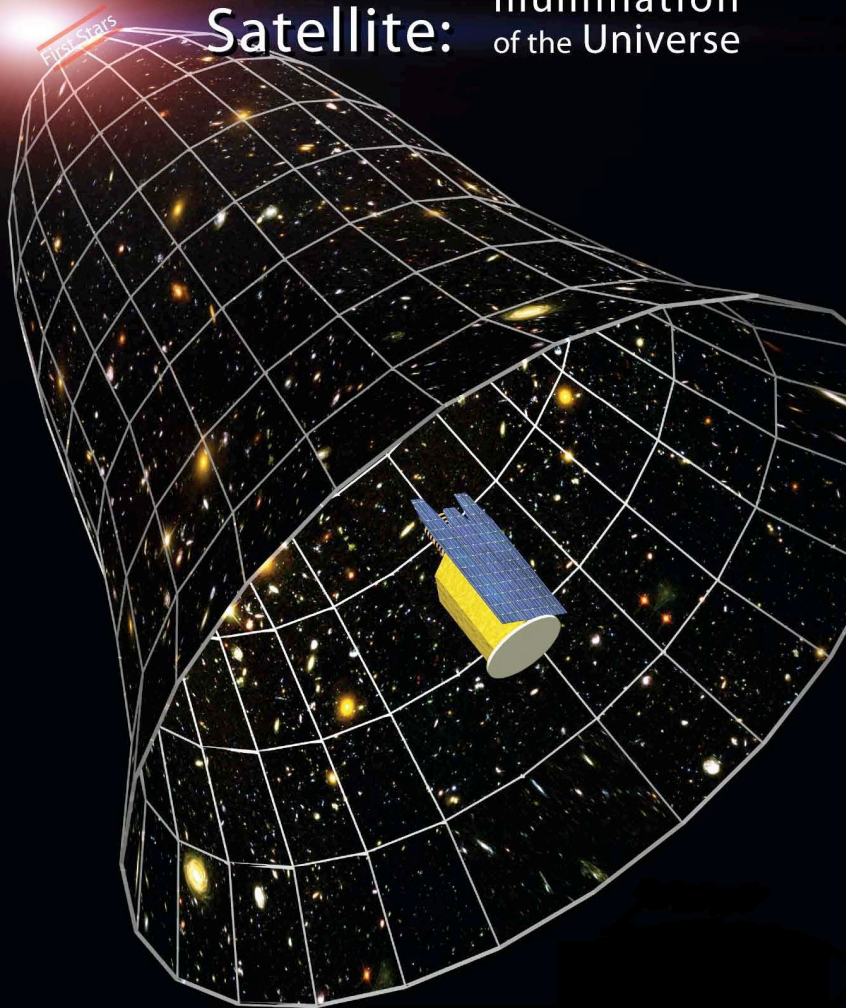


Joint Astrophysics Nascent Universe Satellite:

Observing the
Illumination
of the Universe

13.7 Billion Years



Using GRBs to study the high- z Universe (the JANUS mission)

David Burrows
The Pennsylvania State University

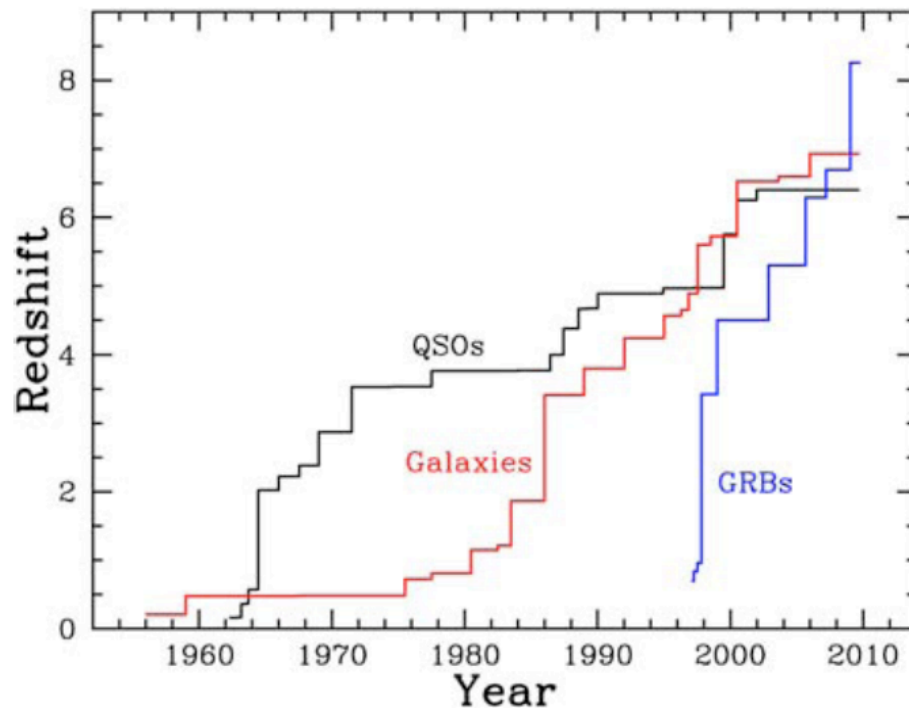


GRBs and Swift

20 November
2004



N. Tanvir. private communication

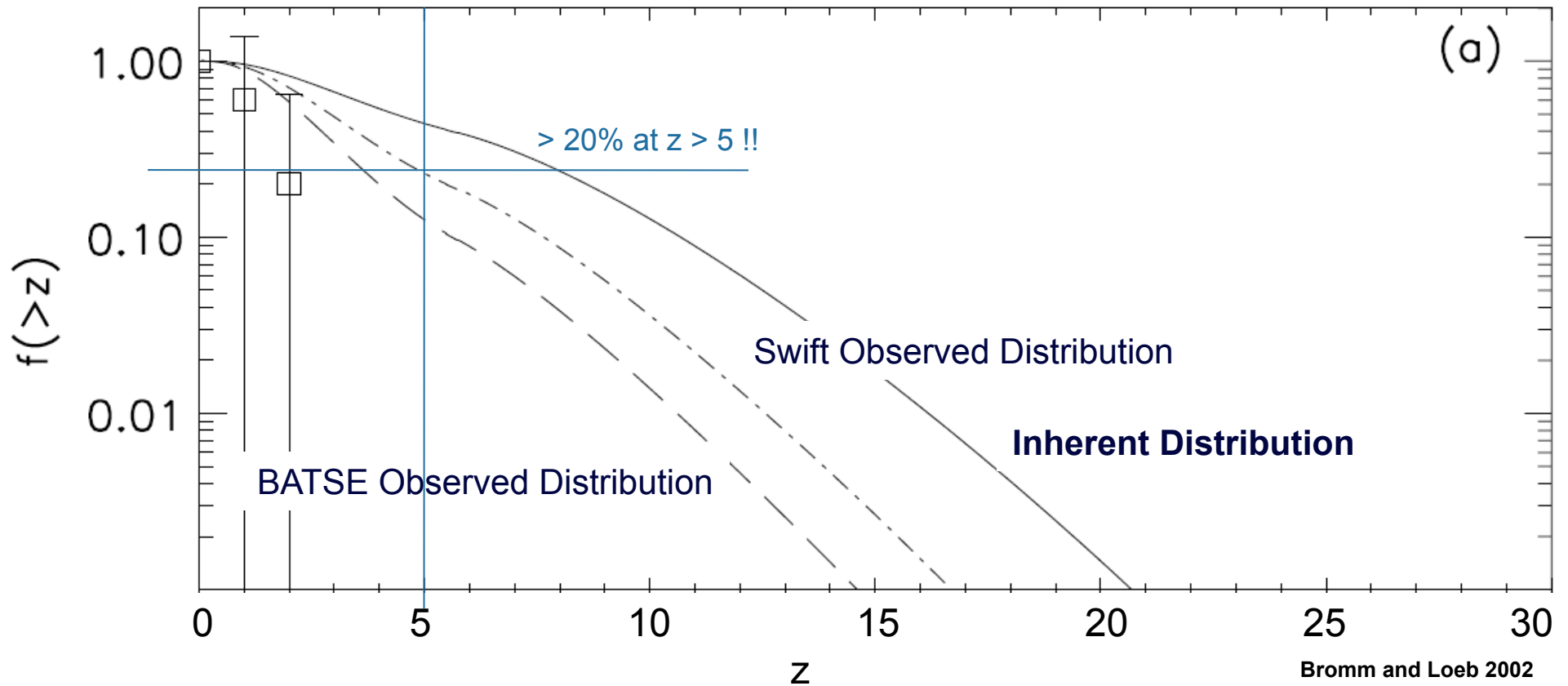


Rapid GRB localizations by *Beppo-SAX*, *HETE-2*, and *Swift*:

- Dramatic increase in GRB max redshift
- Use of GRBs to probe high- z hosts and IGM



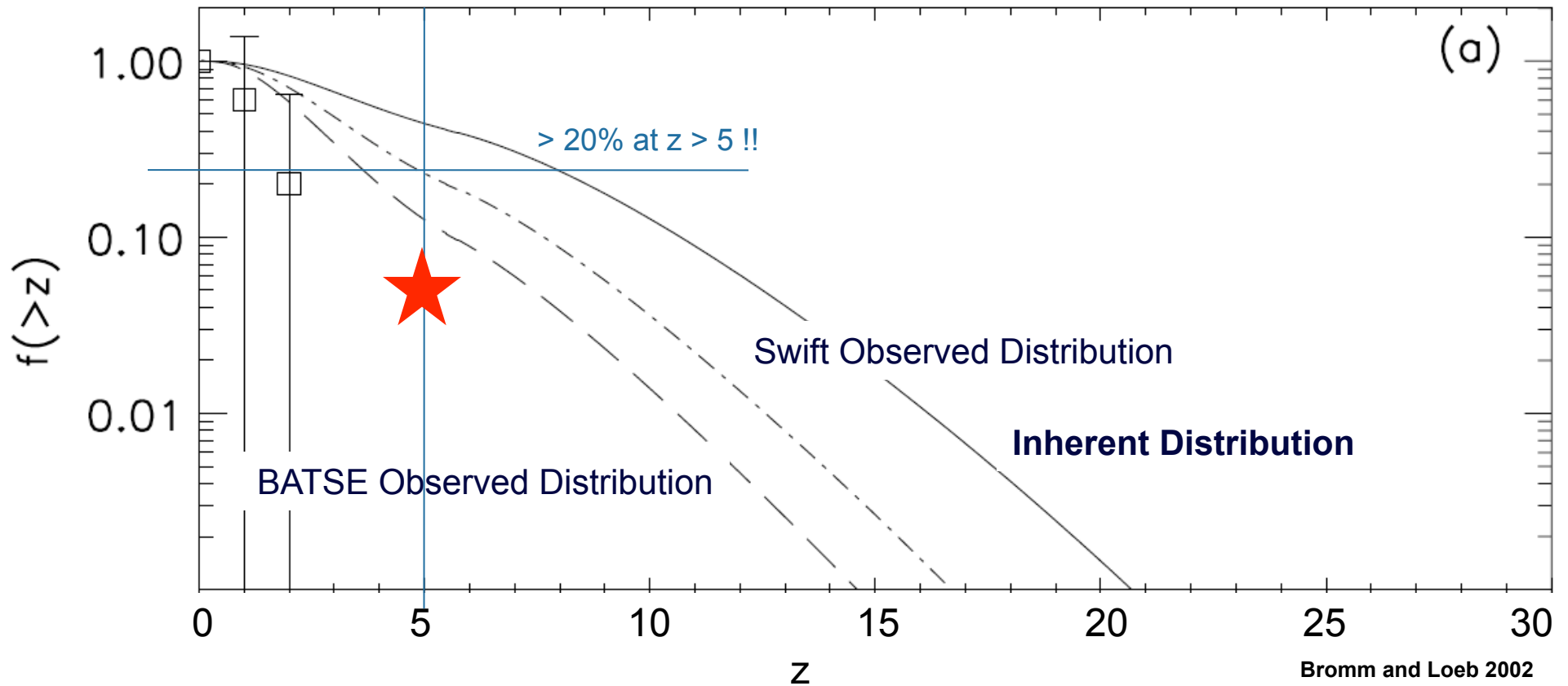
GRB Redshift Distribution



\Rightarrow 20% of Swift bursts should have $z > 5$



GRB Redshift Distribution

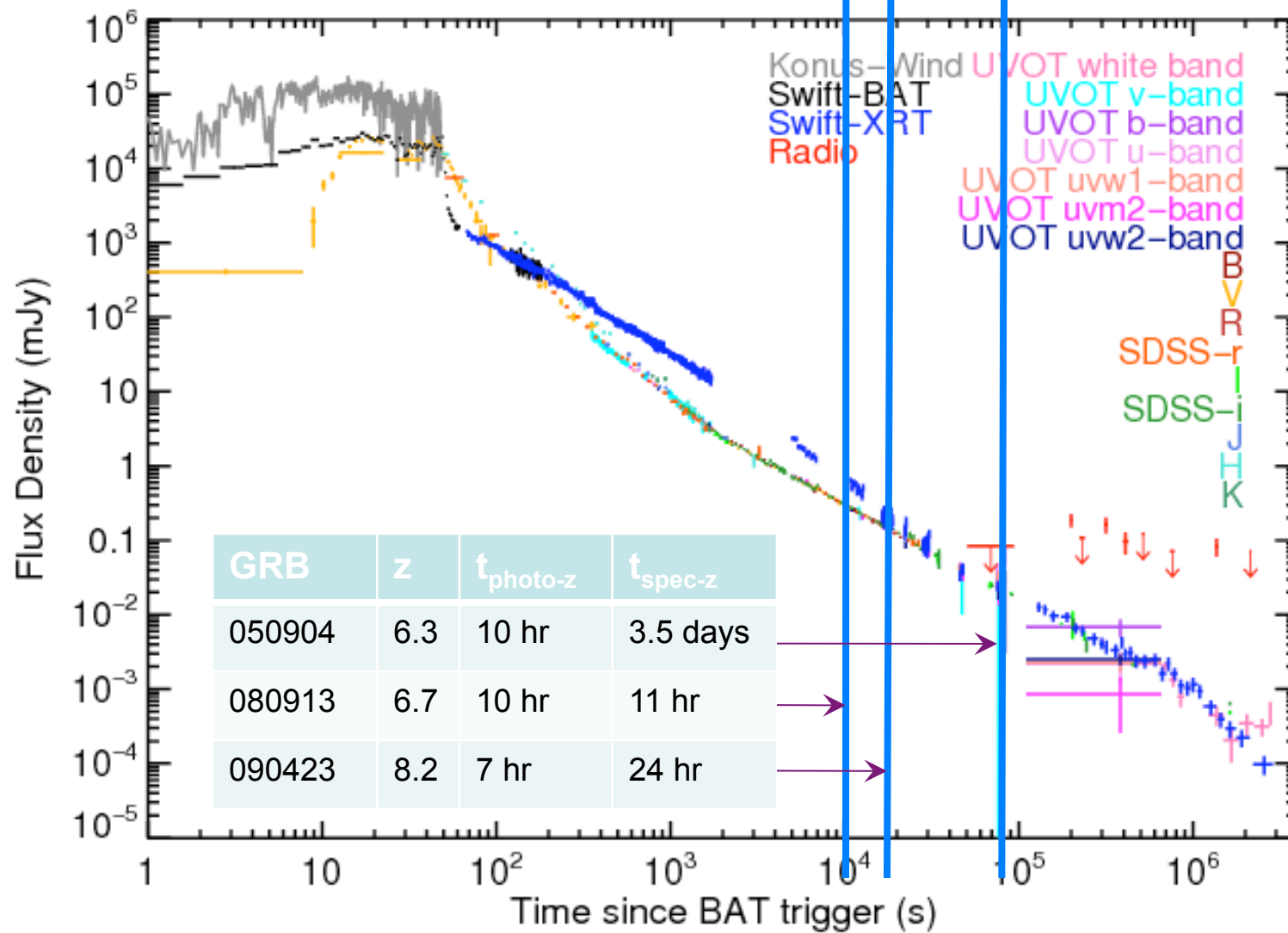


⇒ 20% of Swift bursts should have $z > 5$
⇒ Observed fraction with $z > 5$ is only 5%

- 1) GRB Luminosity function ?
- 2) Observational bias ?



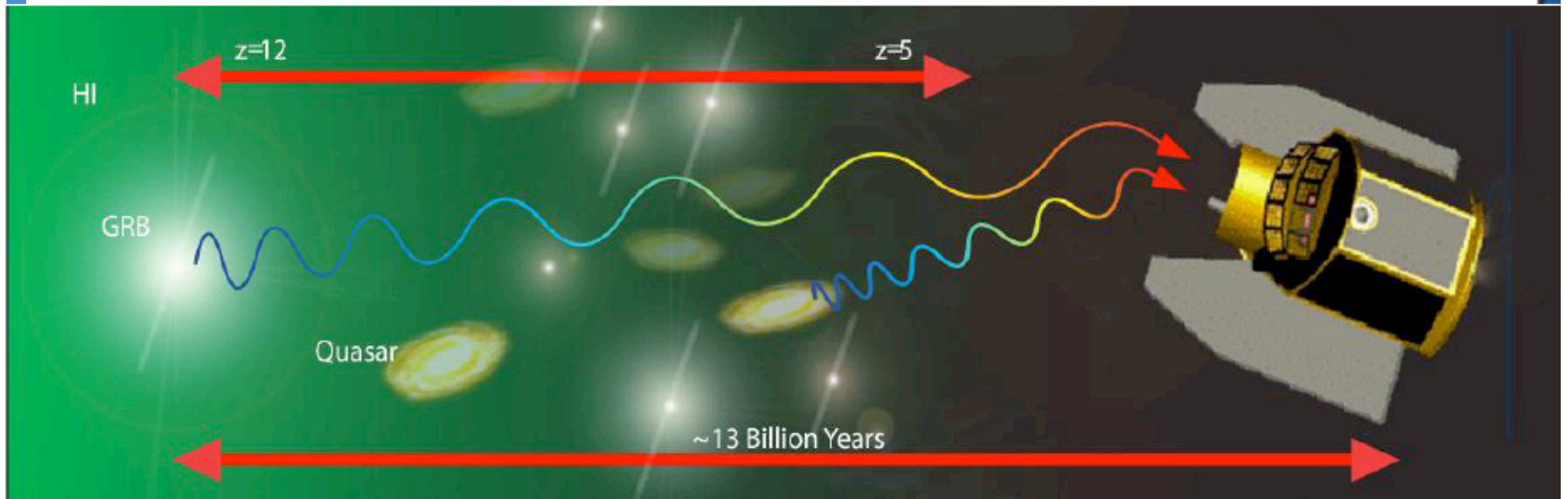
Observational Bias





JANUS

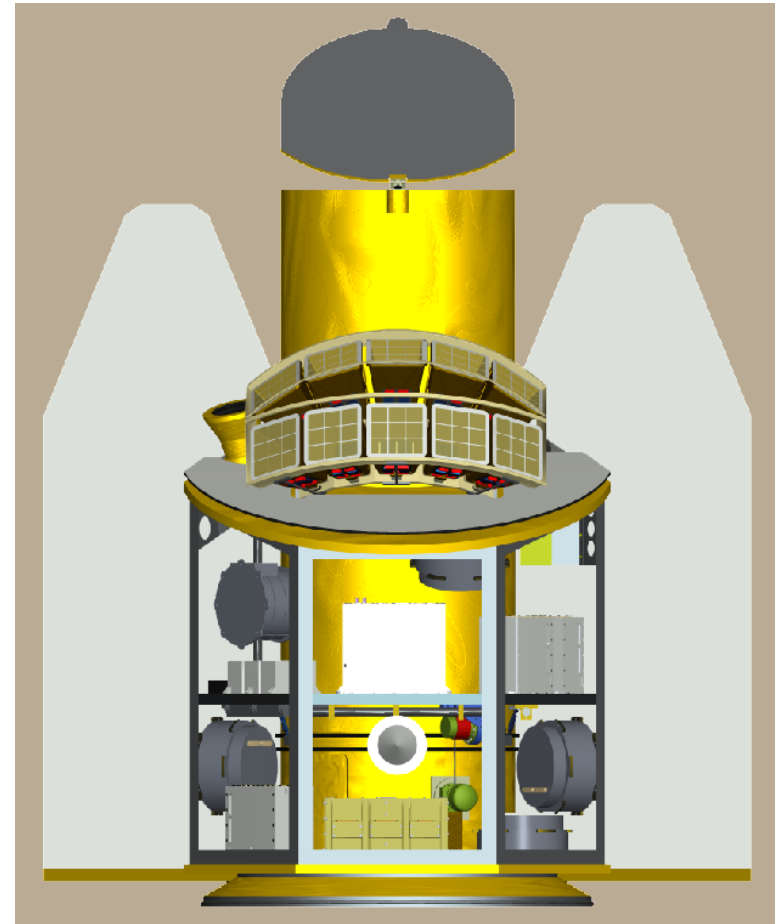
- Designed to discover high redshift GRBs and quasars
- X-ray Coded Aperture Telescope (0.5-20 keV) + NIR Telescope (0.7-1.7 μm , $R=14$)
 - Optimized for detection and identification of high- z GRBs
 - > 50 GRBs with $5 < z < 12$
 - Star formation rate, finder for ground-based followup
 - 20,000 sq degree spectroscopic sky survey to discover > 400 QSOs @ $6 < z < 10$





The *JANUS* Concept

- NASA Explorer mission
- Combines aspects of *Swift* and SDSS
 - *Swift* gamma-ray burst detection and observation – catching cosmic explosions “on the fly”
 - Sloan Digital Sky Survey quasar survey – discovering the end of the reionization era
- Fine-tuned for high redshift
 - Lower-energy burst monitor (XCAT)
 - Near-infrared imaging/spectroscopy (NIRT), $0.7\text{--}1.7\ \mu\text{m}$
 - Larger telescope than *Swift* + built-in (low-resolution) spectroscopy
 - Retains rapid response of *Swift*

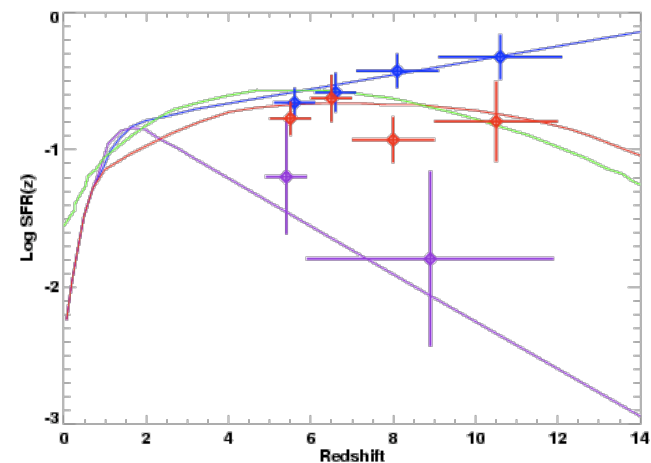
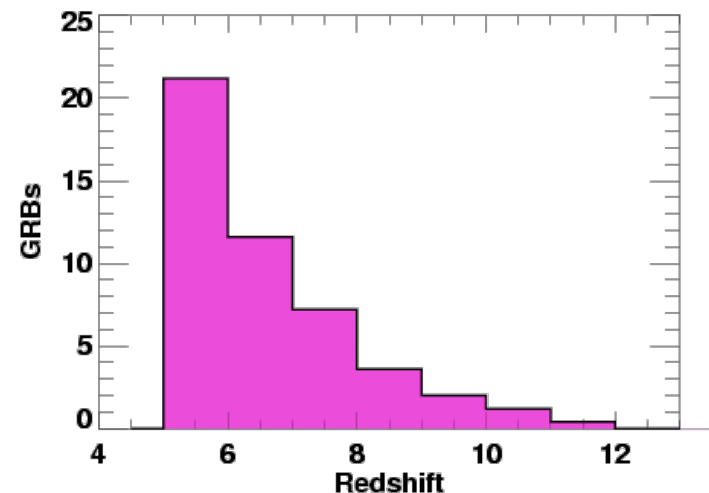




JANUS Science: Objective 1

Measure the cosmic star formation rate over $5 < z < 12$ by detecting and observing high-redshift gamma-ray bursts and their afterglows.

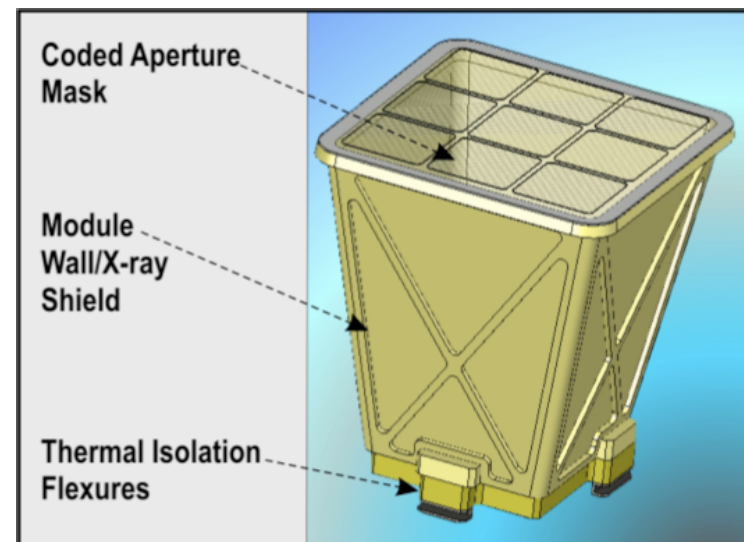
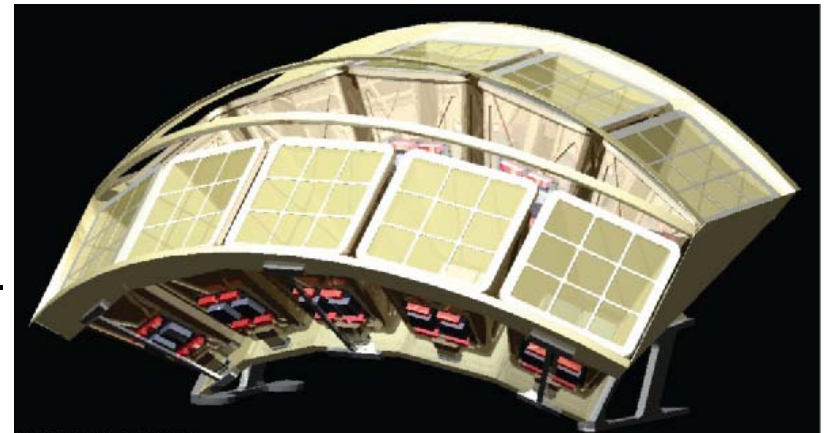
- JANUS will detect 50 bursts at $z > 5$ over its two-year mission
- Burst detection with XCAT leads to slew and NIRT observation
- Afterglow position, flux, and redshift derived from NIRT data
- JANUS burst redshifts will reveal the cosmic star formation rate over $5 < z < 12$
- Stellar light was likely the dominant cause of the cosmic reionization
- Star formation estimates are crucial to constructing a full picture of reionization





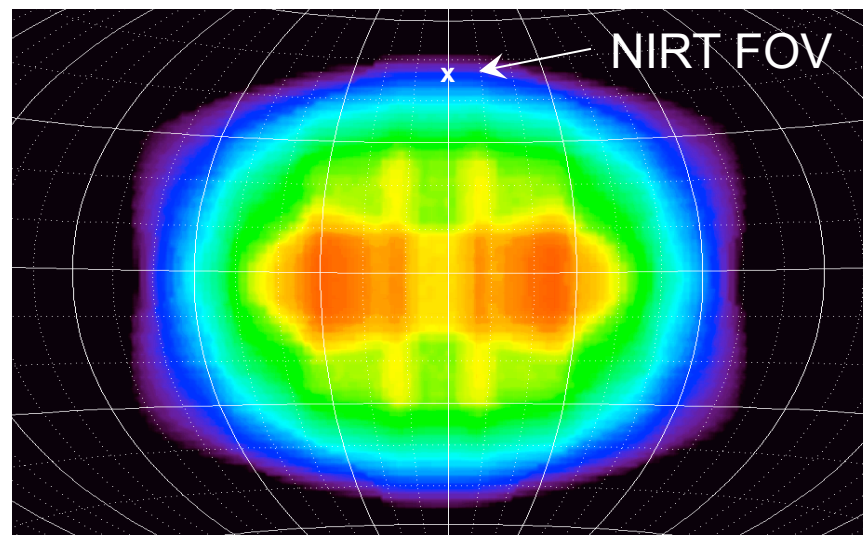
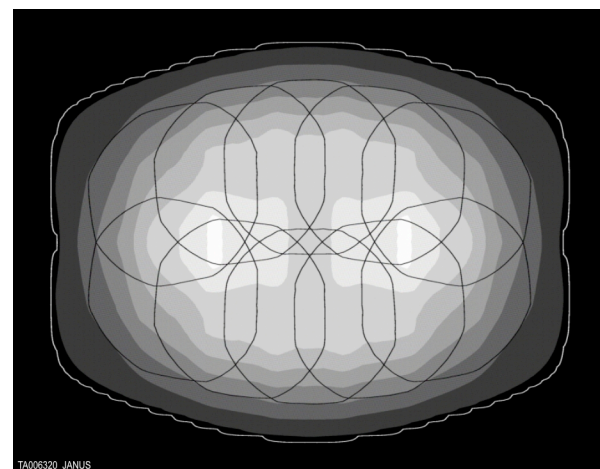
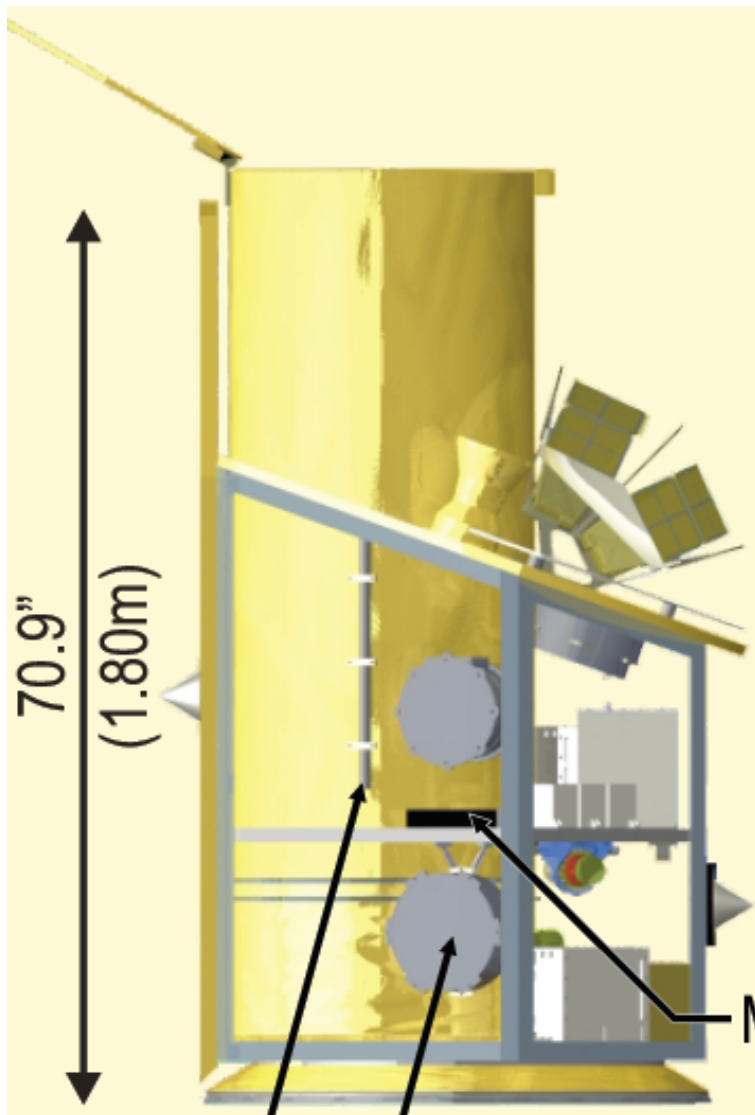
X-ray Coded Aperture Telescope (XCAT)

- **David Burrows (PSU), Lead**
- Covers twice the sky area of *Swift* (1/3 of all-sky)
- Lower-energy range to catch higher-redshift bursts (1–20 keV)
- Improved position accuracy (20")
- 10 modules arranged in 2x5 “caterpillar” format
- For each module:
 - Coded aperture “shadow mask”
 - 4 hybrid CMOS detectors (Si)
 - Integrated readout electronics
- Triggering software from *Swift* BAT team (LANL)





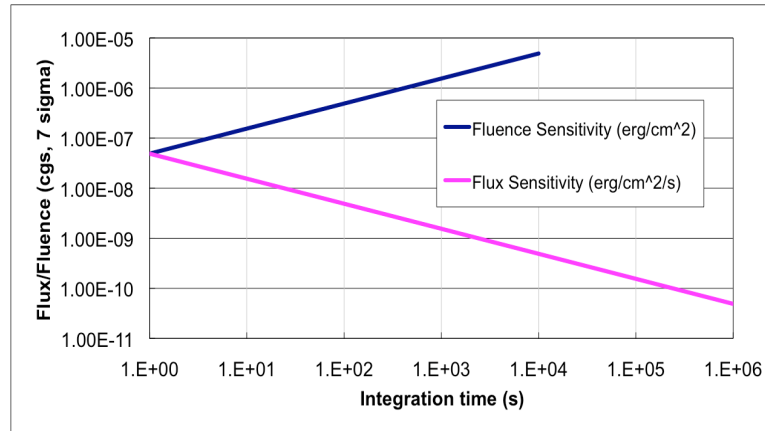
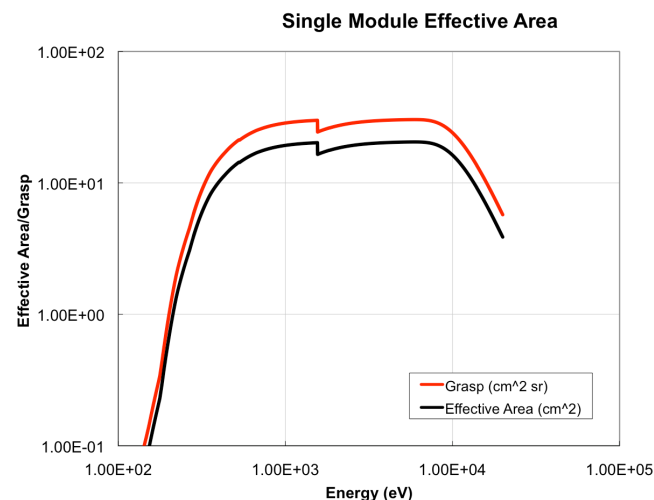
Large Field of View





X-ray Coded Aperture Telescope (XCAT)

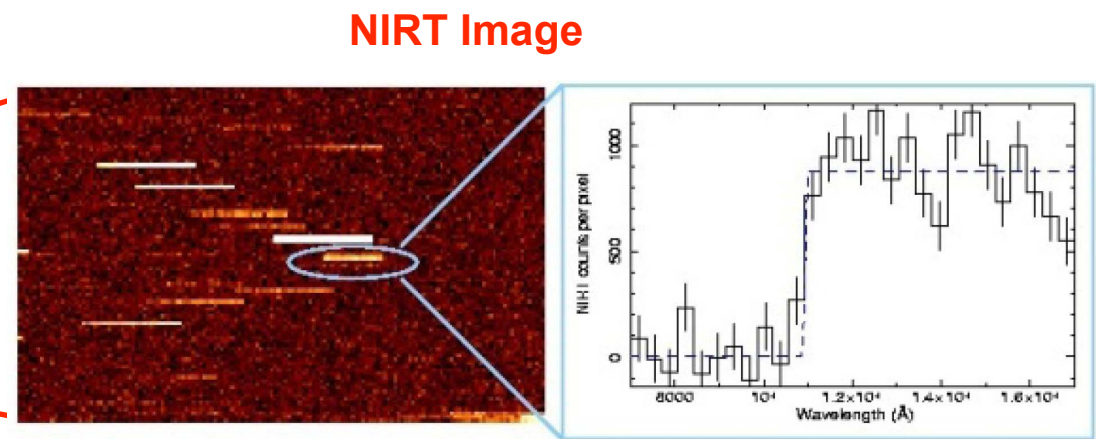
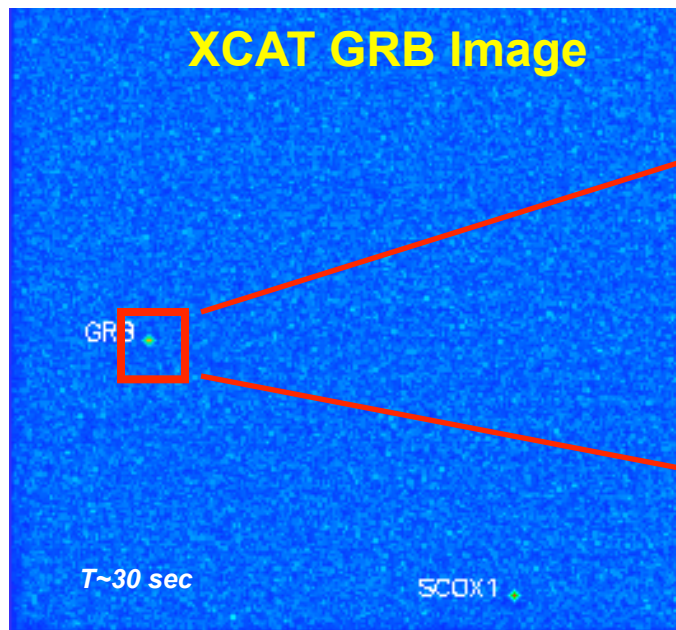
Parameter	XCAT
Bandpass	1 – 20 keV
FoV	3.9 sr
Ang. Resolution	6.3' (30") FWHM
Effective Area	21 cm ²
$\Delta E/E$	7% (<3%)
Δt	0.5 s
DXRB rate	$\sim 540 \text{ cts s}^{-1}$
Internal Bkgnd	< 1 cps
Pt Src Sensitivity	240 mCrabs (7σ , 30s)
Triggering	<i>Swift</i> BAT Heritage





JANUS GRB Response

- XCAT detects and localizes X-ray Flashes and Gamma-Ray Bursts for follow-up by NIRT
 - XCAT determines position to $\sim 30''$ in about 30 s
 - XCAT sends position to S/C and to ground
 - XCAT telemeters detailed light curve and spectral info

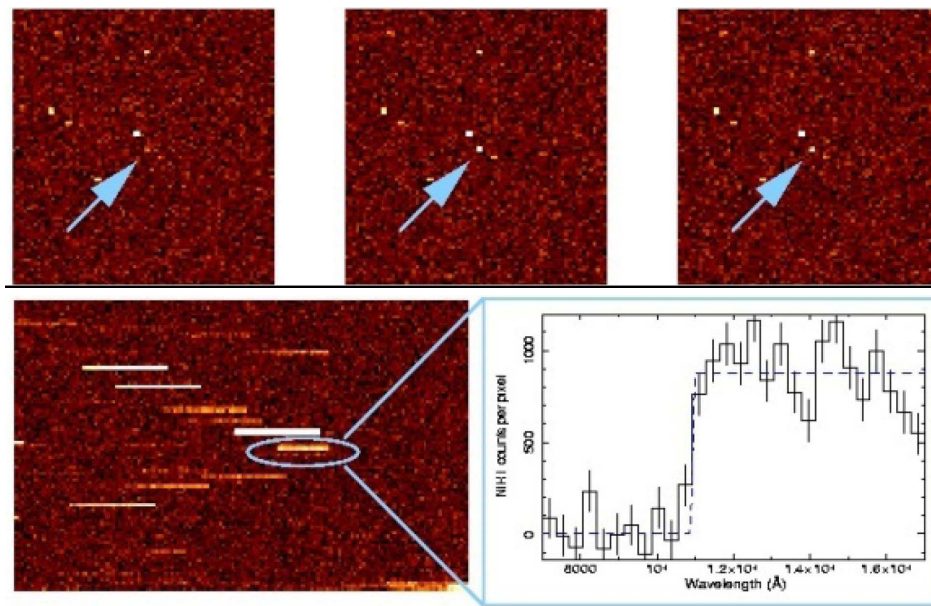
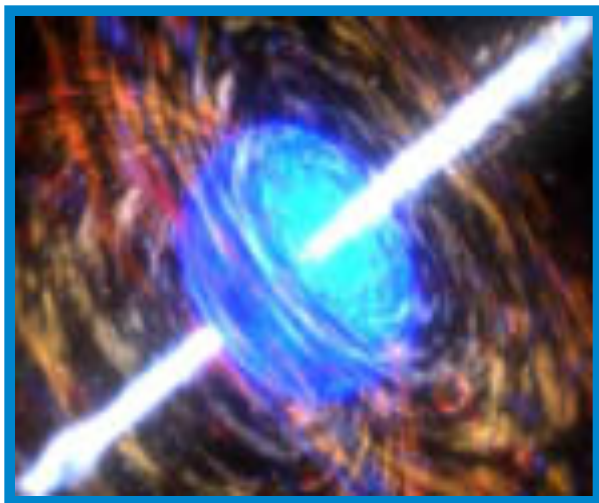


- NIRT telemeters spectral info



JANUS GRB spectroscopy

~30 GRBs ($6 < z < 12$)

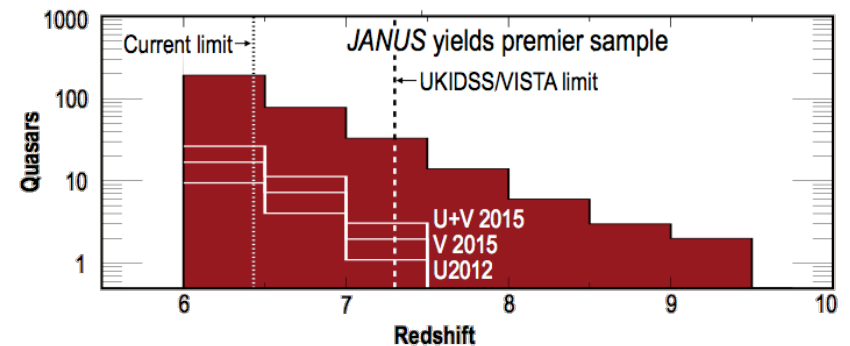
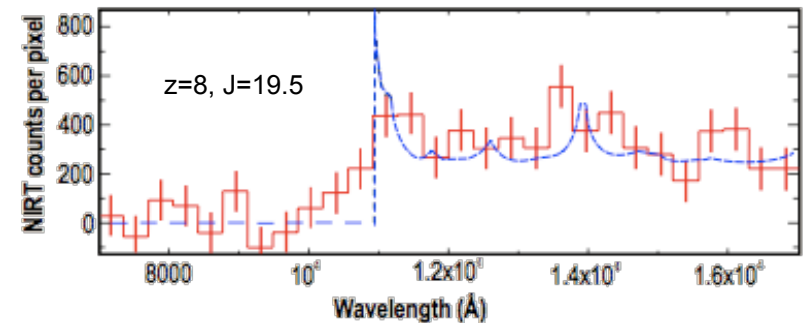




JANUS Science: Objective 2

Enumerate the brightest quasars over $6 < z < 10$ and measure their contribution to reionization.

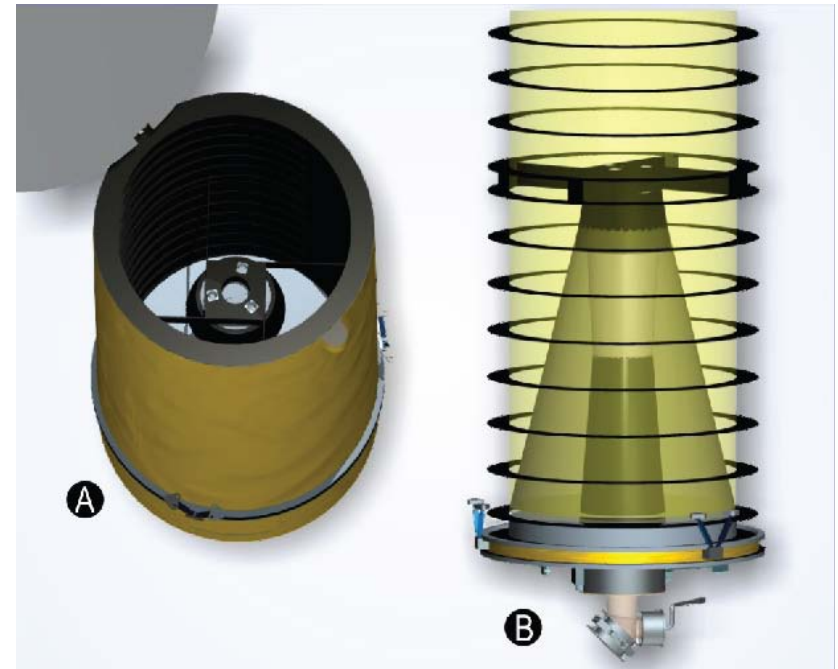
- JANUS will carry out a 20,000 deg² objective-prism survey in the 0.7–1.7 μ m bandpass
- Reaching $J=19.6$ mag in the continuum (4σ) with resolution $R \approx 14$
- Anticipate 400 quasars at $z > 6$, well beyond the capability of ground-based surveys
- Redshift and ionizing flux of each quasar measured directly from NIRT data
- Also anticipate discovery of the nearest and coolest (Y-class) brown dwarfs



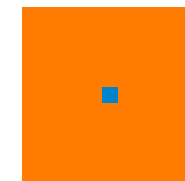


Near-Infrared Telescope (NIRT)

- **Terry Herter (Cornell)**, Lead
- 50-cm aperture
- Direct imaging and low-resolution (objective prism) spectroscopy
- Covers 0.36 deg^2 , $0.7\text{--}1.7 \text{ }\mu\text{m}$, in a single exposure
- Lyman-alpha over $5 < z < 13$
- Two redundant rotating optical elements switch modes
- Detect and characterize afterglows of high- z gamma-ray bursts
- Field of view allows 1/2-sky survey



JANUS
Field-of-View

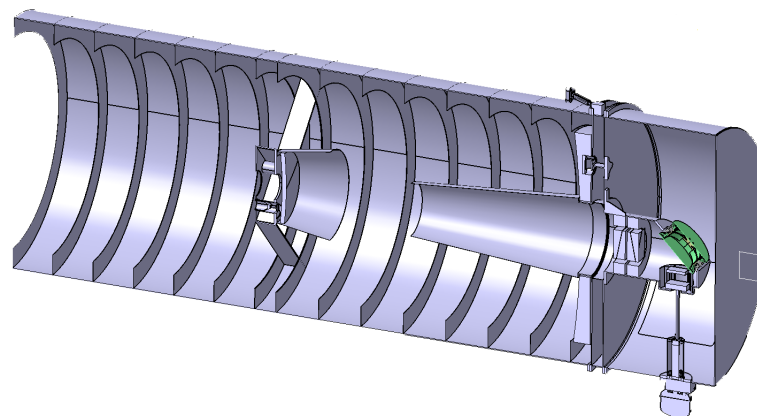
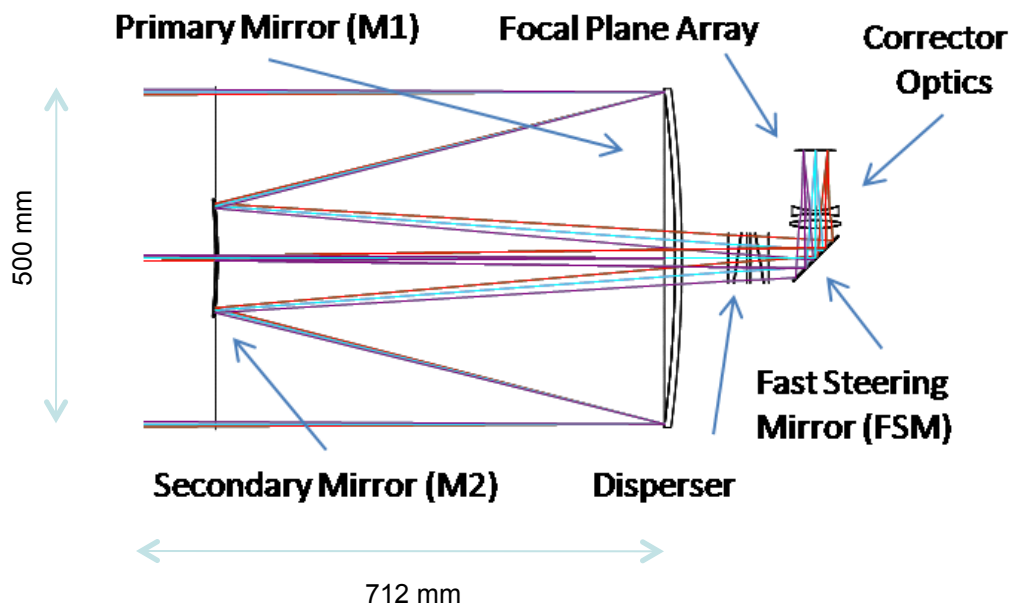


JWST
Field-of-View



JANUS Near Infrared Telescope

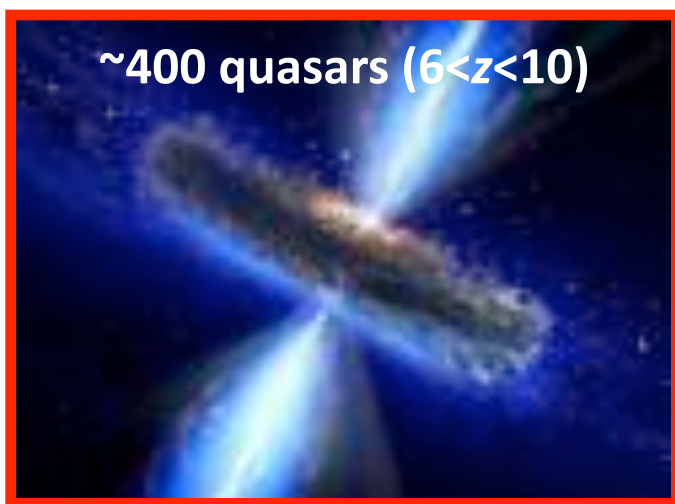
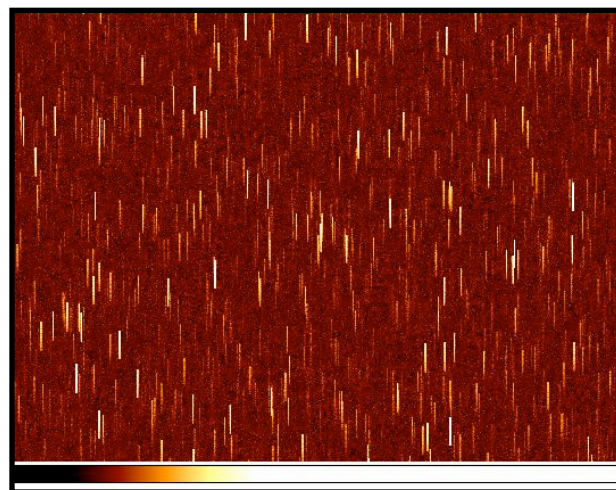
Parameter	NIRT
Aperture	0.5 m
Bandpass	0.7 – 1.7 μ m
FoV	0.36 x 0.36 arcmin ²
Ang. Resolution	< 1.5 arcseconds
$\lambda/\Delta\lambda$	> 10
Zodiacal Bkgnd	5-12 e ⁻ /s/pixel
Imaging Sensitivity	J=20.3 (S/N=5, 60s)
Dispersed Sensitivity	J=19.6 (S/N=4, 480 s)
Focal Plane	H2RG @ 150K



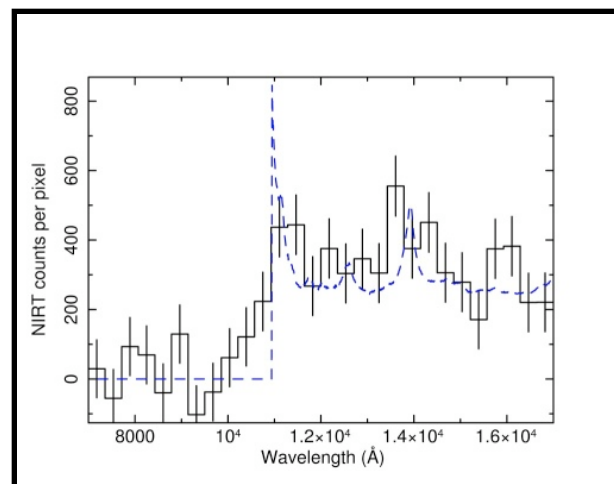


JANUS Quasar Survey

20,000 square degree
survey (5×10^8 spectra)
to $J=19.6$



~400 quasars ($6 < z < 10$)

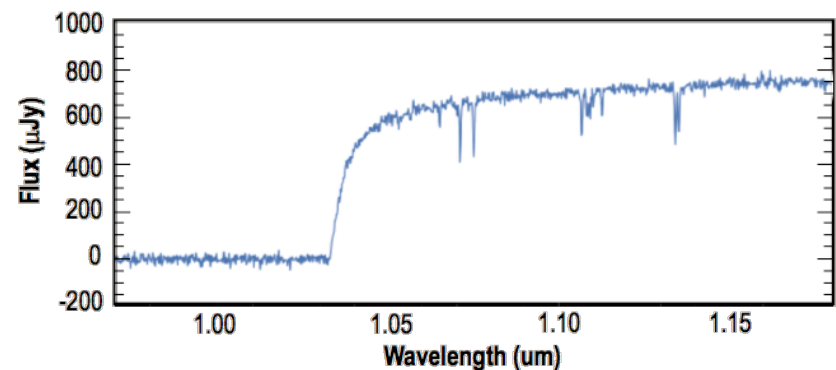




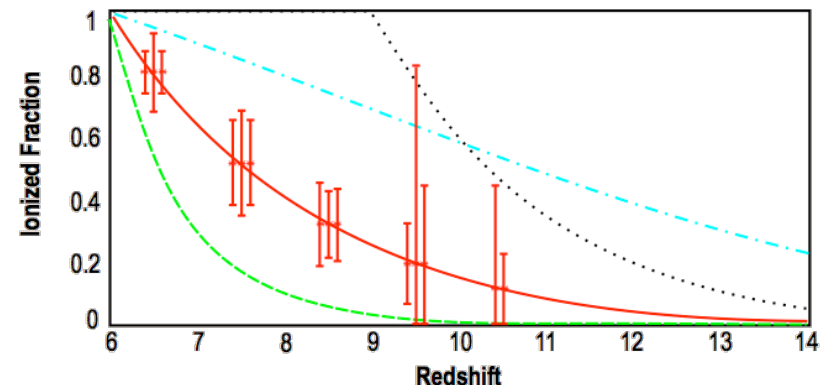
JANUS Science: Objective 3

Enable detailed studies of the history of reionization and metal enrichment in the early Universe.

- Every JANUS burst and quasar will be bright enough for observation with current facilities
- Burst alerts reported in real time, including position, brightness, and redshift
- JANUS bursts will be used to measure the ionized fraction in the intergalactic medium
- Quasar catalog updated at 3-month intervals
- Each quasar will be a rewarding target for upcoming satellite and ground-based observatories



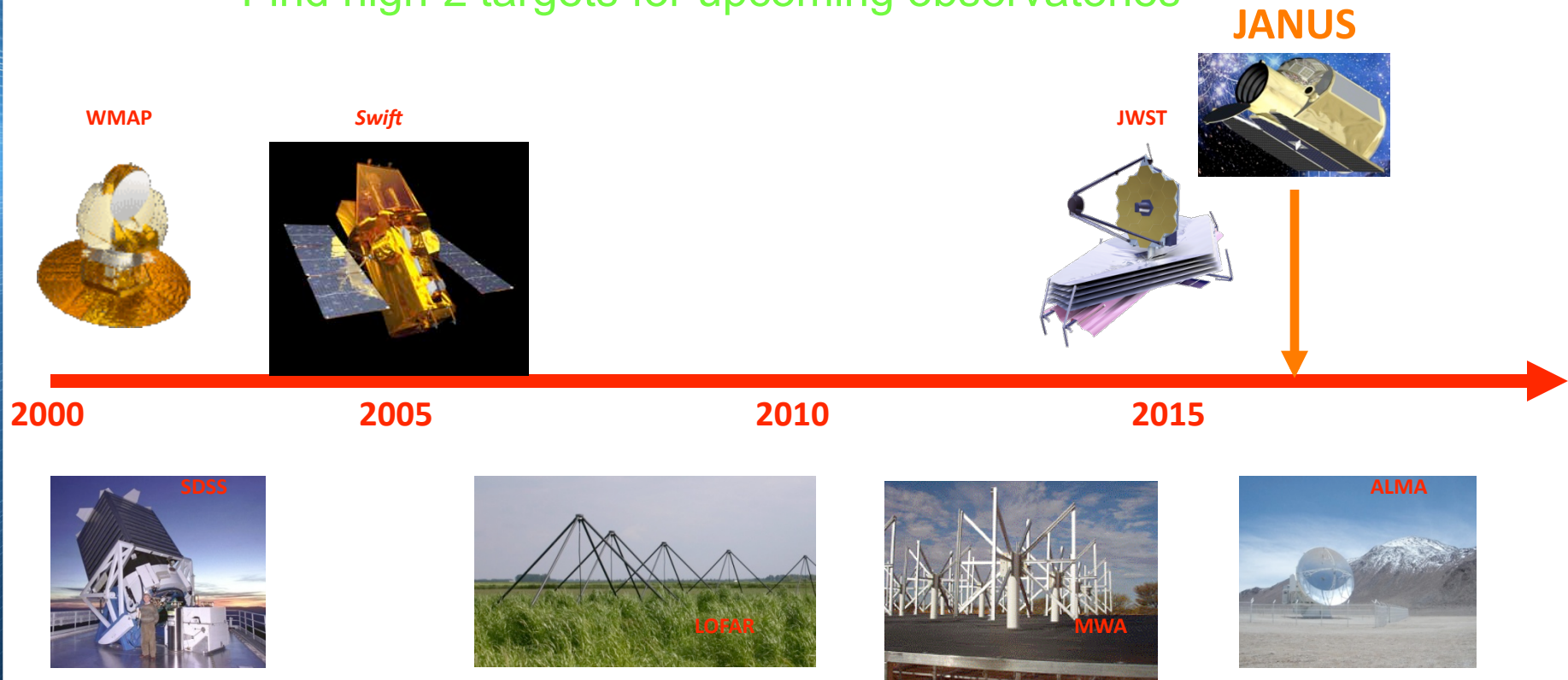
Simulated 1500s VLT spectrum of J=15 quasar @ $z=7.5$





JANUS Context

- Success of *Swift* & SDSS provide confidence that GRBs & quasars are strong probes of this early period
- *JANUS* provides strong synergy in a field with new & ambitious facilities designed to explore reionization:
 - Find high- z targets for upcoming observatories





JANUS Status

- Proposed to NASA in 2007 as SMEX
- Completed Phase A study
- Will be re-proposed in 2010 as Explorer
- Launch date ~ 2016





Summary

- Scientific exploitation of high- z GRBs to study cosmology is in its infancy, but recent discoveries are encouraging.
- *JANUS* mission will provide rapid localizations of high redshift GRBs and QSOs to spur work in this area.

